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Full Plane STWAVE: SMS Graphical Interface

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PURPOSE: The purpose of this Coastal and Hydraulics Engineering Technical Note (CHETN) is to describe the graphical interface for the full-plane version of the wave model STWAVE (Smith et al. 2001; Smith 2001; and Smith and Smith 2002) that has been added to the U.S. Army Corps of Engineers (USACE) Surface Water Modeling System (SMS). A subsequent publication will describe the capabilities added in the full plane version of the model.

BACKGROUND: STWAVE solves the steady-state conservation of spectral wave action along backward traced wave rays (Smith 2001). The model is used to compute wave transformation (refraction, shoaling, and breaking) and wind-wave generation. Previous versions of STWAVE operated on a half plane, meaning that only wave energy traveling within a 180-deg arc is considered (i.e., wave energy propagating from offshore to the beach). The half-plane assumption is appropriate for most open coast applications, but for bays, lakes, or complex shorelines, wave transformation and generation on the full 360-deg plane is required. The full-plane version of STWAVE (STWAVE-FP) includes several changes to model input, output, and modeling procedures. These include the potential specification of spectral inputs on all edges of the computational domain, additional model parameters, and new file formats. This CHETN describes the interface developed for STWAVE-FP and the file formats associated with the model.

STWAVE-FP FILES: Four input files are required for an STWAVE-FP simulation (Figure 1), which include the simulation (*.sim), the model parameters (*.std), the depths (*.dep), and the input spectra (*.eng). Current (*.cur) and structures (*.struct) files are optional. The name of the simulation file can be passed to the STWAVE-FP model as a command line argument or the model may be launched from inside of SMS. Depending on the options selected, STWAVE-FP creates between one and five output files (Figure 1). The wave field file (*.wav) is always generated and provides the wave height, peak period, and mean wave directions over the entire STWAVE-FP grid. Optional output files include output spectra at selected cells (*.obs), output spectra at nesting cells (*.nst), wave breaking information (*.brk), and wave radiation stress gradients (*.rad).

The simulation file stores the names of all the files that contain data related to the simulation. This includes the files used by STWAVE-FP and three other files that are used by the SMS interface. These additional files contain parameters used to define the input spectra (*.txt), a filtered list of the input spectra (*.wavespec), and a mapping of which spectra are applied to which grid boundaries for individual wave cases (*.stc). All the potential input and output files are listed in Figure 1, and a description of each file is given in Table 1. All STWAVE input and output files are in SI units, but the user can work in non-SI units in SMS, and SMS will automatically convert to SI units when the files are saved.

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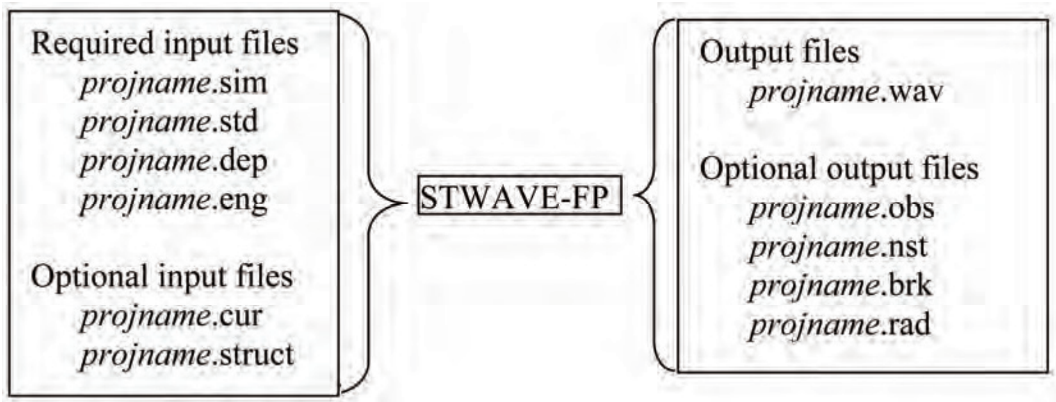

Figure 1. Files involved in STWAVE-FP simulation

Table 1
Files Involved in STWAVE-FP Simulation

File Name	Type	Description
projname.sim	Input – required	Input and output filenames for the simulation
projname.std	Input – required	Model parameters and output options
projname.dep	Input – required	Water depths at all grid cells
projname.eng	Input – optional	Input wave energy spectra – this includes one spectra for each open boundary for each wave case. Wave spectra may be repeated
projname.struct	Input – optional	List of cells containing structures
projname.cur	Input – optional	Current at each cell (u, v components in x,y directions).
projname.wav	Output – always	Wave height, period and direction for each cell
projname.obs	Output - optional	Transformed energy spectra at selected cells
projname.nst	Output - optional	Transformed energy spectra at cells to input to nested grid simulation
projname.brk	Output - optional	Breaking flag or energy dissipated at each cell due to breaking (depending on breaking option)
projname.rad	Output - optional	Radiation stress gradients (in x,y directions) at each cell

STWAVE-FP INTERFACE: The interface for the full-plane version includes the same components as the interface for the half-plane version. The same general modeling steps, outlined in Smith (2001) are still recommended. In this document, the principal components of the interface will be presented. Differences specific to the full-plane version are highlighted.

Like other finite-difference models in SMS, STWAVE-FP is controlled through the *2D Cartesian Grid Module*. The user should select the *Set Current Model* command in the *Edit* menu and choose *STWAVE-FP* to activate the model interface. When STWAVE-FP is selected as the current model, the STWAVE-FP menu and tools become available. It is recommended that the user become familiar with other modules of SMS to fully exploit the interface. For example, the STWAVE-FP grid can also be specified in the *Map Module* via a *STWAVE-FP Coverage*. In addition, in most simulations the user will use the *Scatter Module* to import surveys and digital maps to define bathymetry for a grid.

STWAVE-FP Menu. The *STWAVE-FP* menu (Figure 2) commands are listed in Table 2 along with a description of each command.

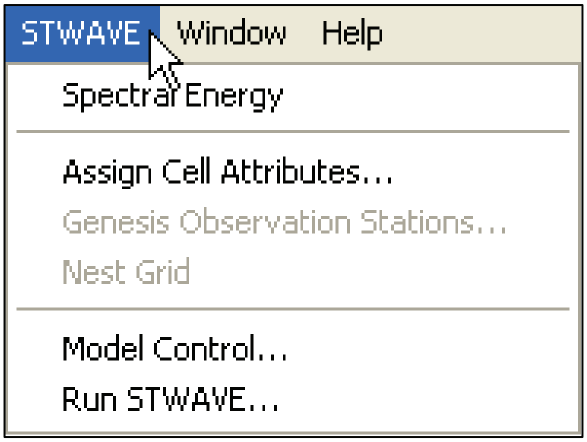

Figure 2. *STWAVE-FP* menu

Table 2
STWAVE-FP Menu Commands

Command	**Functionality**
Spectral Energy	Brings up the spectral energy dialog to define/view wave energy spectra to be used in this simulation. Spectral generation is described in its own section.
Assign Cell Attributes	This command is used to assign cell attributes. A cell can be a typical ocean cell, a special ocean cell (spectral output computed at these), a typical land cell, or a structural cell.
Genesis Observation Stations	This command is only available when a Genesis grid is loaded into the SMS. This command places observation cells to correspond to the Genesis grid.
Nest Grid	This command is available when multiple grids are loaded into the SMS. It allows parent-child relationships to be created between the grids.
Model Control	Brings up the Model Control dialog to specify model parameters.
Run STWAVE-FP	Launches STWAVE-FP with the currently loaded simulation. As the model runs, a dialog monitors progress of the model and gives the user status messages. When the run is complete, the spatial solutions are read in for analysis and visualization.

STWAVE-FP Tools. The STWAVE-FP tools are listed in Table 3 along with their icon and functionality. In SMS, one tool is active at a time. The active tool may be a model specific tool such as those listed in the following table, or it may be a general tool such as *Pan*, *Zoom*, or *Rotate*. The active tool controls what response the program will make when the user clicks or drags the mouse through the graphics window. Typically there are two types of tools, those that are used to select entities and those that are used to create entities. In the STWAVE-FP interface, the user can create a grid and then select cells within that grid. Multiple cells can be selected using the tools for selecting columns or rows, or by dragging a box or polygon around more than one entity, or by holding down the **SHIFT** key while sequentially clicking on entities.

Table 3
STWAVE-FP Tools

Tool	Icon	Functionality
Select Cell		Allows the user to select a computation point (cell) by graphically clicking on it. STWAVE-FP works on a “cell centered” grid meaning that its computation points are at the centers of the cells. Once selected, the user can adjust the elevation of the cells or assign them attributes.
Select Row		Allows the user to select an entire row of cells by clicking on any cell in the row.
Select Column		Allows the user to select an entire column of cells by clicking on any cell in the column.
Create Grid		Allows the user to create a computational grid by clicking three corners of the grid.

Creating a Grid. The process for creating a STWAVE-FP model grid consists of four steps:

a. Read in bathymetric data. These data can be from one or more surveys, or from another numerical model simulation (e.g., an ADCIRC mesh converted to a scatter set). Data should be brought into SMS as a scattered data set or a digital elevation map (DEM). The most common formats are described as an *.xyz or *.pts file in the SMS documentation. Data for the coastlines and structures in the modeling domain could either be included in the bathymetry (recommended) or brought into SMS separately and merged with the bathymetry data inside SMS. Within STWAVE-FP, water depths are positive numbers and land elevations are negative numbers. STWAVE operates in a Cartesian coordinate system, so bathymetry in geographic coordinates must be converted to State Plane or UTM prior to creating the grid. SMS offers a number of coordinate conversions (Zundel 2005).

b. Select STWAVE-FP as the working model. In the *Cartesian Grid Module*, under *Data* menu, find *Switch Current Model* submenu and select *STWAVE-FP* as the working model.

c. Define modeling domain. Zoom into the area around the computational domain and select the *create grid tool*. To define the extent of the modeling domain, the user must click three times in the graphics window. The first click (Pt 1) is at the grid origin (STWAVE local $x = 0$, $y = 0$). Then the user should move the cursor (a line will appear from the selected corner) along the STWAVE-FP x-axis and click again (Pt 2). Finally, the user must move the cursor to define the extent of the y-axis and click again (Pt 3). Figure 3 shows a grid being defined.

d. Create a grid. After defining the grid domain, the *Map->2D Grid* dialog appears (Figure 4). This dialog allows the user to modify the size, orientation, position and cell size for the grid that is being created. The grid position and orientation are initialized from the three points digitized in the previous step. If more exact locations are known, the user would enter these in the top section of the dialog. In the center section, the individual cell size is entered. Previous versions of STWAVE supported only square cells; however, STWAVE-FP is more general and allows rectangular cells. The default values create a grid with 10 x 10 cells, so these values must be changed by the user to the desired values. In the lower section of this dialog, users tell SMS to interpolate the bathymetry values for the grid from the scattered data. There is also an option to interpolate current data to the grid. Once these data are entered, the user clicks the **OK** button, and a grid is created. Bathymetry values for each cell of the grid (along with current values if that was

specified) will be interpolated from the scattered bathymetry data to the cell centroids. Grid cells with a negative depth value will be classified as dry land and excluded in the STWAVE-FP calculations. After the grid is created, the user can also select cells and modify depth values and cell classifications.

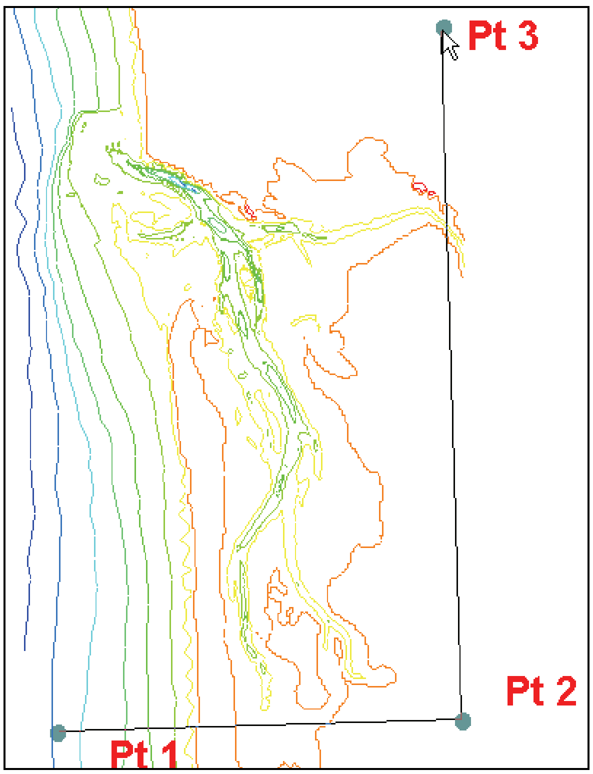

Figure 3. Creating a grid

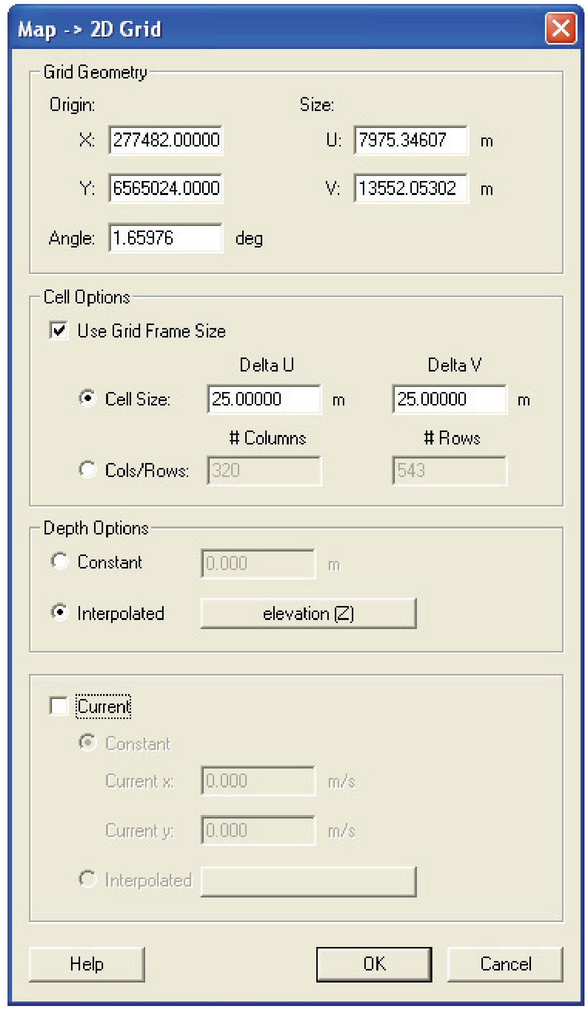

Figure 4. Map ->2D grid dialog

Editing a Grid. Cell depths and attributes in the STWAVE-FP grid may be edited, but the grid itself cannot be repositioned once it is generated. To reposition or change the resolution of a grid, a new grid should be created. This is required if the domain is enlarged or reduced, the grid cell size is modified, or the grid orientation is adjusted to align with principal wave directions. Various operations are permitted for editing STWAVE-FP grid cells. These include:

a. Specification of individual cell depth/elevation. Select one or more cells using the *select cell tool*, and specify a depth/elevation value in the edit field located at the top of the application (just below the menus). This feature could be used to represent the effects of a dredging or shoal-mining on the wave field by deepening areas in the grid or represent the effect of dredged material mounds in the modeling domain by reducing depths, etc. This feature is useful

when changes to the underlying bathymetry are desired in a small section of the modeling domain where such changes can be made manually to a subarea or selection of cells.

b. Classification of grid cells as land, structure, water, or monitoring station (special output) location. This is done by selecting one or more nodes using the *Select Cell* tool and specifying the cell attributes using the *Assign Cell Attributes* command in the STWAVE-FP menu. This brings up the STWAVE-FP *Cell Attributes* dialog. Wave spectra (.obs file) and a summary file of wave parameters (selhts file) will be written out for the monitoring station location(s).

Defining Spectra. Boundaries conditions for STWAVE-FP consist of energy spectra at open boundaries. This requires that the user define these spectra. The spectra can be generated from an external source, and read in from an energy ".eng" file, or created using the spectral energy command in the menu. This brings up the *Spectral Energy* dialog shown in Figure 6. To generate spectra, the user must first create a spectral grid. The *Create Grid* button allows the user to specify the number and distribution of frequencies and the directional bin size.

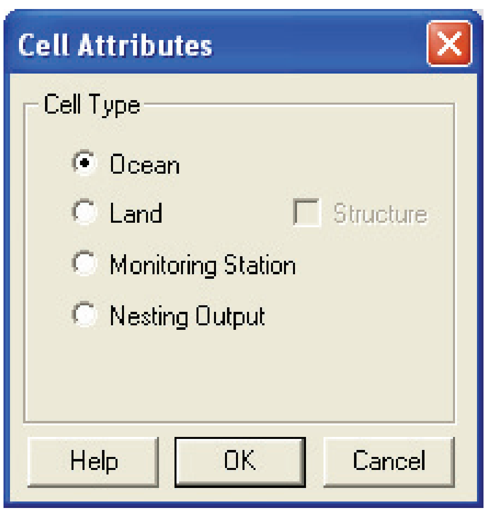

Figure 5. STWAVE-FP *Cell Attributes* dialog

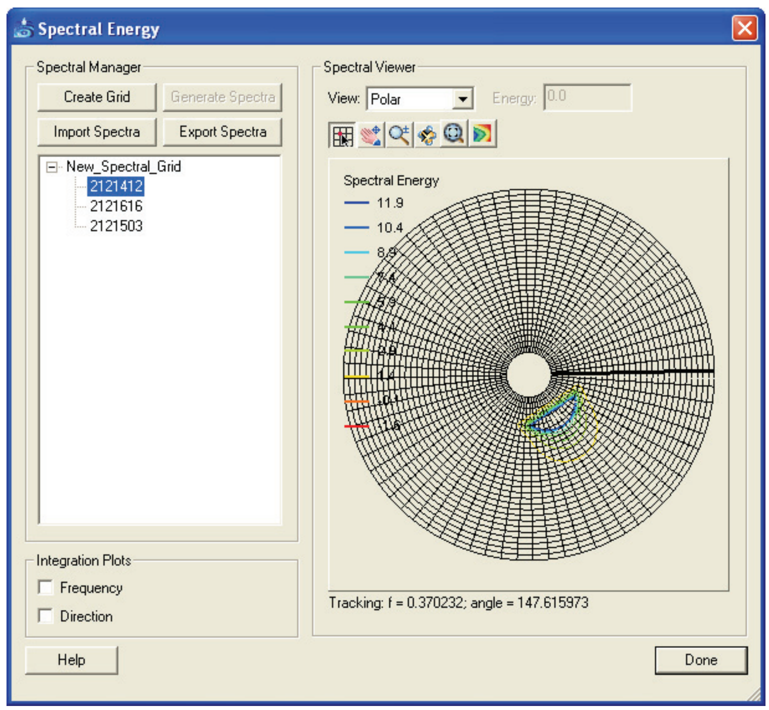

Figure 6. *Spectral Energy* dialog for spectra visualization and generation

Once the spectral grid exists, the user can use the *Generate Spectra* button to generate spectra from parameters. The spectral types supported are shown in Table 4. Parameters used to generate spectra are stored in a tabular text file with the simulation for later reference. As can be seen in Figure 6, the spectra cover the full 360-deg plane. The dialog allows the visualization of the spectra in three dimensions and integrated frequency and directional distributions.

Table 4
Spectral Parameters

Spectral Shape	Required Parameters
TMA (Arbitrary Water Depth)	Significant Wave Height (H_s) Peak Wave Period (T_p) Gamma (frequency spread) nn (directional spread) Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
JONSWAP	H_s and T_p or Wind Speed and Fetch Distance Gamma Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
Bretschneider (ITTC)	Significant Wave Height (H_s) Peak Wave Period (T_p) Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
Pierson-Moskowitz	Wind Speed or H_s or T_p Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
Ochi-Hubble Double Peak	H_s for the low frequency H_s for the high frequency T_p for the low frequency T_p for the high frequency Gamma for the low frequency Gamma for the high frequency Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not

Model Control Parameters. The *Model Control* command in the STWAVE-FP menu brings up the *Model Control* dialog shown in Figure 7.

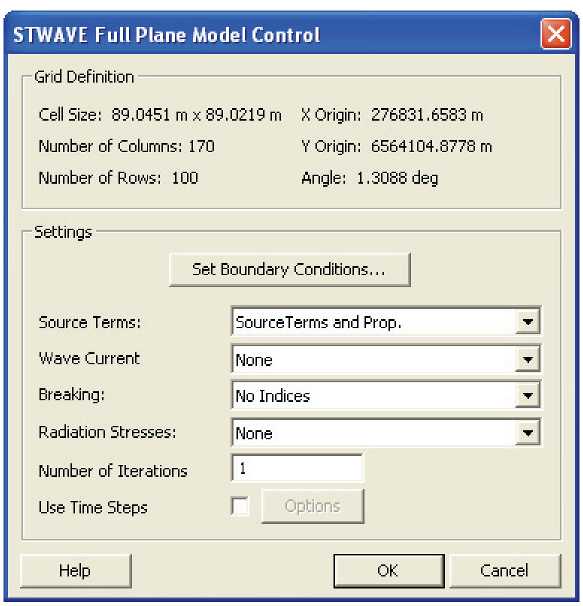

Figure 7. STWAVE-FP *Model Control* dialog

This dialog is divided into two parts as follows:

a. Grid definition. This section describes the grid. It is for information only and can not be modified.

b. Model settings. This section includes combination boxes for model settings including computational options and output options. It also includes a button to set the boundary conditions for each wave case to be considered and a toggle to tell SMS whether to interpret these cases as individual scenarios or quasi-time-steps of events.

- Set boundary conditions. STWAVE-FP allows input of multiple wave cases or events in a single run. Further, each edge of the domain may potentially have waves entering across the boundary. The *Set Boundary Conditions* button in the model control brings up the *STWAVE Boundary Condition* dialog (Figure 8). In the upper left quadrant of the dialog, the user selects the type of boundary for each of the four edges of the domain. This can be a zero spectrum (land or open boundary), 1-D transformed spectrum (lateral boundary, waves are transformed along the boundary assuming the bathymetry is 1-D), or spectrum from file (specified wave spectra, see **Defining Spectra**). In the lower left quadrant, the user defines the number of wave cases to be simulated. Each row of the spreadsheet defines a case to be simulated. For each case, the user defines the wind direction, magnitude, tidal/surge elevation and input spectrum (for each boundary that needs a spectrum). These are chosen by selecting the cell in the spreadsheet, and double clicking in the list of defined spectra that appears on the right side of the dialog.

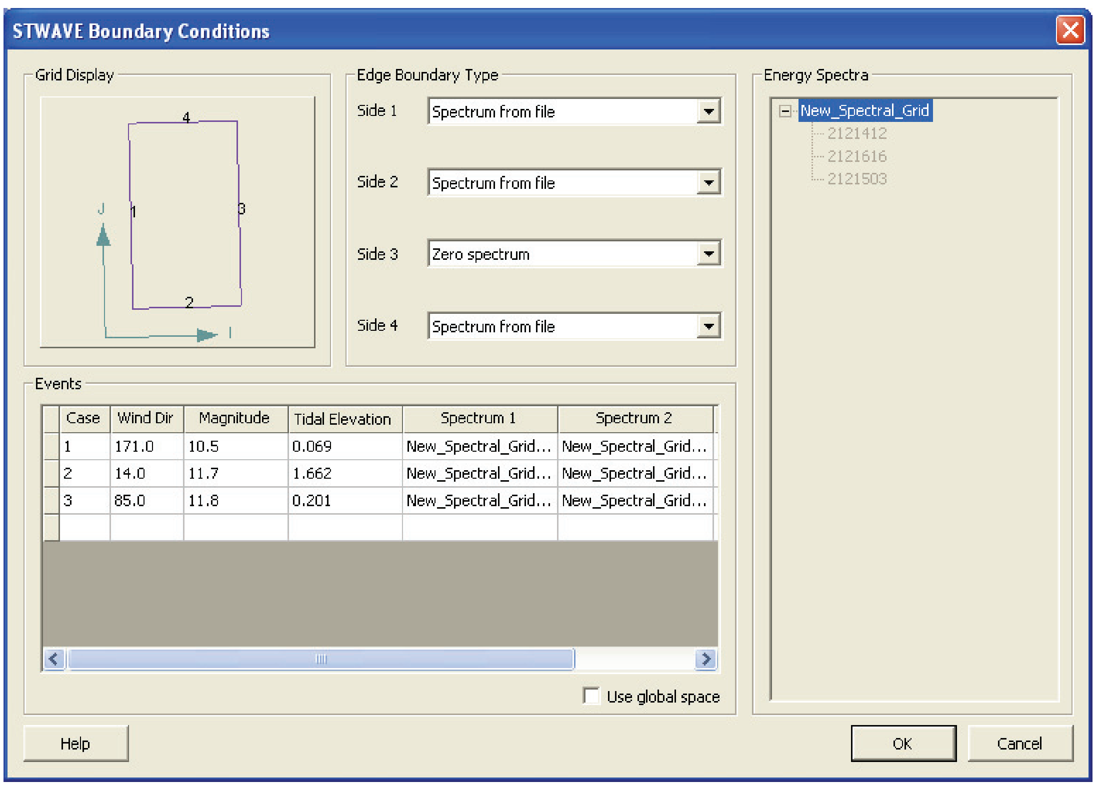

Figure 8. Wave case *Boundary Condition* dialog

- Source terms. This option can be either *Source Terms and Prop*. or *Propagation Only*. If propagation only is chosen, no wind wave growth is included in the simulation (and the simulation executes faster).

- Wave current. Presently, the full-plane version of STWAVE does not include wave-current interaction. The options in the future will be *none* for no wave-current interaction, *currents* for including wave-current interaction, and *constant for all spectra* for a single current field applied to all input conditions. The options with currents will require a *projname.cur* input file.

- Breaking. This option allows the user to identify where within the grid waves are breaking. The option *write indices* will write out a field of ones (for breaking) and zeros (for no breaking) to the *projname.brk* file to identify breaking locations. The option *no indices* will not create breaking file.

- Radiation stresses. This option specifies whether radiation stresses will be calculated (*calculated*) or not (*none*). Radiation stresses are wave momentum fluxes that can be fed into a circulation model to generate wave setup and nearshore currents.

- Number of iterations. Waves in shallow water can refract significantly, so wave propagation cannot always be solved in four progressive sweeps of the grid. Thus, for complex areas, multiple iterations may be required in the model. The number of iterations is specified here.

- Use time-steps. STWAVE-FP is a steady-state model, but it can be run in a quasi-time stepping mode (series of steady simulations). This option lets the user identify times to case or event identifier.

SUMMARY: Various features, tools, and analysis capabilities outlined in this document are designed to enhance the ability of engineers to efficiently utilize the STWAVE-FP in SMS. This CHETN provides specific guidance to users to ensure a comprehensive understanding of the interface necessary for the most efficient usage of STWAVE-FP. With the usage of the model in engineering projects by the user community, both the model and its interface are expected to evolve, and the current interface will continue to undergo revisions. Feedback and suggestions from users on the design, implementation, and usage of the present version of the STWAVE-FP interface are welcome.

ADDITIONAL INFORMATION: The Transformation-Scale Waves work unit of the U.S. Army Corps of Engineers, Navigation Systems Research Program, funded this research. Questions about this CHETN can be addressed to Dr. Jane McKee Smith (601-634-2079, e-mail: *Jane.M.Smith@erdc.usace.army.mil*). This CHETN should be referenced as follows:

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